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STRATEGIC PLAN TO DEVELOP AND EVALUATE "DOLPHIN-SAFE" METHODS OF FISHING FOR YELLOWFIN TUNA IN THE EASTERN TROPICAL PACIFIC

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STRATEGIC PLAN

TO DEVELOP AND EVALUATE "DOLPHIN-SAFE" METHODS OF FISHING FOR YELLOWFIN TUNA IN THE EASTERN TROPICAL PACIFIC

GOALS AND OBJECTIVES

MAY 1992

By

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STRATEGIC PLAN TO DEVELOP AND EVALUATE METHODS OF FISHING FOR YELLOWFIN TUNA IN THE EASTERN TROPICAL PACIFIC THAT ARE "DOLPHIN-SAFE".

BACKGROUND

In 1976 the Inter-American Tropical Tuna Commission's duties were expanded to include maintaining porpoise stocks at or above levels that assure their survival in perpetuity, with every reasonable effort being made to avoid needless or careless killing of porpoise. Since then, the Commission has developed specific programs to 1) monitor the population size and incidental mortality of porpoise stocks and 2) reduce porpoise mortality through gear research and education of skippers. Most of the latter has been directed at improving the existing technology, where purse-seine nets are intentionally used to encircle associations of porpoise and tuna with the subsequent release of the porpoise.

In 1988, the U.S. Congress amended the U.S. Marine Mammal Protection Act (MMPA) to, among other things, provide specific direction in determining the comparability of foreign dolphin protection programs to U.S. standards. Because failure to meet the comparability standards results in an embargo against importing tuna into the U.S., a great deal of controversy has been generated about the efficacy of the legislation. In addition, the issue was further confounded in the fall of 1991 when the GATT panel responsible for ruling on Mexico's claim made a preliminary ruling in favor of Mexico. Further, in April 1990 several major U.S. tuna processors announced that they would no longer buy tuna caught in the ETP in association with porpoise (often referred to as "porpoise fishing").

The tuna-porpoise problem in the ETP has caused considerable turmoil within and between countries that traditionally catch, process, export or import tuna. In addition, this issue has created problems for the environmental community because 1) replacing porpoise fishing with alternative fishing methods may create even worse by-catch problems for other species and 2) replacing porpoise fishing with alternative fishing methods may significantly reduce the long-term yield of yellowfin tuna in the ETP. Further, the embargo process tends to reduce cooperation among nations, at a time when additional cooperation is required.

The purpose of this document is to outline a strategic plan and comprehensive approach for gathering information on tunas and dolphins in the ETP and on methods of fishing for tunas in the ETP. Over the next 12 months, it is hoped that this

information will result in improvements in the existing methods of fishing for tunas such that dolphin mortality is reduced to kill rates between 0.0 and 0.5 dolphins killed-per-set. Over the next 24 - 36 months, it is hoped that this information will result in methods of fishing for tunas that result in zero dolphin mortality. It should be noted that an international commitment to this program is necessary for the program to be successful.

Several nations and organizations have made commitments to provide funds for research activities similar to those described in this plan. At present, the U.S. has made approximately $1.3 million available for studies in 1992. Most of this funding is being dedicated to cooperative studies between the IATTC and the NMFS. Where appropriate, these studies have been noted in the strategic plan. Allocation of additional funds to specific activities described in this plan is needed as soon as possible, if the goals of this program are to be realized. Details of the research projects for which funding has been allocated are provided in the appendices to this document.

PLAN BY GOAL AND OBJECTIVE

GOAL 1. DEVELOP AND EVALUATE METHODS OF PURSE SEINE FISHING FOR TUNAS THAT DO NOT INVOLVE CHASING OR ENCIRCLING DOLPHINS

Objective 1.1 Investigate the potential utility of using Fish-Aggregating-Devices to improve the efficiency of locating and capturing yellowfin tuna that are not associated with dolphin in the ETP.

Objective 1.2 Investigate the potential utility of using optical scanners (e.g., laser scanners, low-light level video, etc.) to improve the efficiency of locating and capturing yellowfin tuna that are not associated with dolphin in the ETP.

Objective 1.3 Investigate the potential utility of using remote sensing equipment from either aircraft or satellites to improve the efficiency of locating and capturing yellowfin tuna that are not associated with dolphins in the ETP.

Objective 1.4 Investigate the potential utility of using oceanographic features to improve the efficiency of locating and capturing yellowfin tuna that are not associated with dolphins in the ETP.

Objective 1.5 Investigate the association of tunas and dolphins to determine if there are time periods when tunas

can be caught in the vicinity of dolphin schools, but without having to chase and encircle the dolphins.

Objective 1.6 Determine the food habits of tunas unassociated with dolphins and the food habits of tunas and dolphins that are associated. Use this information to determine if there are any prey items that could be used improve the efficiency of locating and capturing yellowfin tunas in the ETP that are not associated with dolphins.

Objective 1.7 Evaluate other approaches for locating tunas that are not associated with dolphin in the ETP.

Objective 1.8 Evaluate the various approaches and implement field trials for those approaches that are likely to result in catch rates of tuna that are economically feasible .

Objective 1.9 Compare by-catch rates of non-target marine species (e.g., other tunas, undersized tunas, sharks, birds, turtles, and cetaceans) for all proposed alternative fishing methods to by-catch rates of "porpoise" fishing for tunas in the ETP.

GOAL 2. DEVELOP AND EVALUATE METHODS OF PURSE SEINE FISHING FOR TUNAS THAT INVOLVE CHASING BUT NOT ENCIRCLEMENT OF DOLPHINS

Objective 2.1 Investigate the association of tunas and dolphins and determine if there are time periods when tunas can be caught in the vicinity of dolphin schools, but without having to encircle the dolphins.

Objective 2.2 Determine the food habits of tunas unassociated with dolphins and the food habits of tunas and dolphins that are associated. Use this information to determine if there are prey items that would cause tunas to disassociate from the dolphins temporarily .

Objective 2.3 Develop and evaluate the potential utility of acoustic, visual, and chemical stimuli to separate tunas and dolphins that are associated.

Objective 2.4 Develop and evaluate other methods of separating tunas and dolphins that are associated.

Objective 2.5 Evaluate the various approaches and implement field trials for those approaches that are likely to result in catch rates of tuna that are economically feasible .

Objective 2.6 Compare by-catch rates of non-target marine species (e.g., other tunas, undersized tunas, sharks, birds, turtles, and cetaceans) for all of the proposed alternative fishing methods to by-catch rates of "porpoise" fishing for tunas in the ETP.

GOAL 3. IMPROVE THE EXISTING METHODS OF PURSE-SEINE FISHING FOR TUNAS ON DOLPHINS SUCH THAT MORTALITY RATES ARE BETWEEN 0.0 AND 0.5 DOLPHINS KILLED-PER-SET ON AN ANNUAL BASIS FOR THE INTERNATIONAL FLEET

Objective 3.1 Evaluate the following in terms of their potential for reducing the percentage of problem sets: 1) use of Acoustic Doppler Current Profilers to detect subsurface currents, which are associated with "net-collapse"; 2) use of the "Medina double cork line" to reduce entanglement; 3) use of jet boats to free entangled dolphins from the net; 4) use of different types of net materials, cable materials, hang-ratios, and "cork-lines" to reduce the incidence of roll-ups and net collapse; 5) the utility of other approaches to reducing dolphin mortality associated with purse-seine fishing for tunas in the ETP.

Objective 3.2 Determine the extent to which fishing practices for tunas in other regions result in cetacean mortality.

Objective 3.3 Develop and evaluate an international program directed at 1) educating skippers about new developments in purse-seine fishing on dolphins, 2) establishing a skipper performance system under which skippers with unacceptable dolphin-kill rates are either trained or removed from the fleet, and 3) establishing a temporary quota for the international fleet (e.g., 10,000 animals), with the goal of ratcheting this quota to zero over a fixed period of time. Establish a schedule of annual or bi-annual meetings to review progress in achieving the overall goal of eliminating dolphin mortality, while maintaining high yields of tuna in the ETP.

GOAL 4. DEVELOP AND EVALUATE METHODS OF FISHING FOR TUNAS OTHER THAN PURSE-SEINING

Objective 4.1 Evaluate the potential utility of fishing tunas in the ETP with paired trawls, long-lines, or other methods.

Objective 4.2 Compare by-catch rates of non-target marine species (e.g., other tunas, undersized tunas, sharks, birds, turtles, and cetaceans) for all of the proposed

alternative fishing methods to by-catch rates of "porpoise" fishing for tunas in the ETP.

NARRATIVE OF STRATEGIC PLAN

GOAL 1. DEVELOP AND EVALUATE METHODS OF PURSE SEINE FISHING FOR TUNAS THAT DO NOT INVOLVE CHASING OR ENCIRCLING DOLPHINS

The most direct approach to resolving the tuna-porpoise problem in the ETP is to develop fishing practices where dolphins are neither encircled nor chased, but where large yellowfin tuna could be located and captured. To date several possible approaches to date have been identified, such as Fish-Aggregating-Devices and LIDARS, but currently-available information on the feasibility of these approaches or alternative approaches is insufficient to evaluate their suitability.

Objective 1.1 Investigate the potential utility of using Fish-Aggregating-Devices to improve the efficiency of locating and capturing yellowfin tuna that are not associated with dolphin in the ETP.

1.1.1 Approach -

Fish-Aggregating-Devices (FADs) have been used in various fisheries in various regions to attract fish. In the eastern tropical Pacific (ETP), FAD research has been conducted jointly in 1991 by the Inter-American Tuna Commission (IATTC) and the National Marine Fisheries Service (NMFS). Funding for this study was contributed by Bumblebee Seafoods Inc. Efforts were directed at identifying areas where large yellowfin tuna were caught with purse seines on logs or as school fish. FADs were then deployed in these areas. To date too few sets have been made on FADs in the ETP to evaluate their utility in attracting large yellowfin tuna.

1.1.2 Rationale -

The information needed to evaluate the utility of FADs requires the commitment of the industry and governments to inspect FADs for the accumulation of forage and tunas. To date this has not been done. Currently available are FADs that not only communicate position via satellite interfaces and single-side band radio frequencies, but also transmit acoustic information on the degree to which fish have aggregated around the FAD. This type of FAD (referred to as "smart" FADs) has not been used in the ETP to date. It should also be noted that FAD placement will be enhanced by studies on the distribution of large yellowfin tuna, food habits of large yellowfin tuna, and the relationship between oceanographic factors and the distribution of large yellowfin tuna.

1.1.3 Major Activities-

o Design and implement a study based on information gathered during the 1991 FAD experiment to test the hypothesis that large yellowfin tuna can be attracted to FADs (no additional funds available at this time).

o Purchase and distribute FADs that have been shown to accumulate large yellowfin tuna and conduct at-sea trials (no funds available).

o Investigate chemical attractants to enhance effectiveness of FADS (no funds available).

Objective 1.2 Investigate the potential utility of using optical scanners (e.g., laser scanners, low-light level video, etc.) to improve the efficiency of locating and capturing yellowfin tuna that are not associated with dolphin in the ETP.

1.2.1 Approach -

Fishermen currently use dolphins and birds as cues to locate schools of large yellowfin tuna. If dolphins are no longer used as cues, detection rates will decline unless alternative approaches to locating tuna schools are developed. Various sensors that could be carried either on tuna vessels or airborne on ship-based helicopters could be used to enhance detection rates.

1.2.2 Rationale -

To date, no research on the feasibility of using optical scanners, such as LIDARs or low-light video recorders, to detect tuna schools not associated with dolphins has been conducted. In addition, recent advances in night-vision or sensing equipment could prove useful in locating schools of yellowfin tuna in the ETP.

1.2.3 Major Activities-

o Evaluate the feasibility of using Light Detecting and Ranging devices (LIDARs) to locate schools of large yellowfin tuna ($80K by U.S. in 1992- see appendix A).

o Evaluate the feasibility of using low-light video recorders or night-vision devices to locate schools of large yellowfin tuna (Initial studies planned for summer 1992, using equipment on loan from the U.S. army; no additional funds available).

Objective 1.3 Investigate the potential utility of using remote sensing equipment from either aircraft or satellites to improve the efficiency of locating and capturing yellowfin tuna that are not associated with dolphins in the ETP.

1.3.1 Approach -

Fishermen currently use dolphins and birds as cues to locate schools of large yellowfin tuna. If dolphins are no longer used as cues, detection rates will decline unless alternative approaches to locating tuna schools are developed. Various sensors carried by satellites or land-based aircraft could be useful in locating schools of tuna in the ETP. Information to evaluate the feasibility of this approach is not available.

1.3.2 Rationale -

To date, no research on the use of remote sensing techniques to improve the fishermen's ability to locate schools of tuna in the ETP has been conducted. It is conceivable that at least large schools of surface tuna could be detected in real-time using currently available techniques of remote imagery. Achieving this objective will be enhanced by studies on factors that effect the distribution of large yellowfin tuna in the ETP.

1.3.3 Major Activities-

o Investigate the potential use of satellite imagery to locate schools of large yellowfin tuna (no funds available).

o Investigate the potential of using land-based aircraft to carry sensors that could be used to locate schools of large yellowfin tuna in the ETP (no funds available).

Objective 1.4 Investigate the potential utility of using oceanographic features to improve the efficiency of locating and capturing yellowfin tuna that are not associated with dolphins in the ETP.

1.4.1 Approach -

As stated previously, fishermen currently use dolphins and birds as cues to locate schools of large yellowfin tuna. If dolphins are no longer used as cues, detection rates will decline unless alternative approaches to locating tuna schools are developed. Several of the above-mentioned approaches would be more easily evaluated if the distribution of schools of large yellowfin tuna could be related to

various oceanographic parameters.

1.4.2 Rationale -

Yellowfin abundance and catchability have long been presumed to be related to factors such as thermal structure, salinity, wind speed, bottom depth, and primary production. Given the available information on ETP environment, it should be possible to define or predict what oceanographic factors best reflect abundance or catchability of large yellowfin tuna.

1.4.3 Major Activities-

o Evaluate the potential of using environmental information (e.g., temperature, wind data, thermocline depth, primary production, etc.) to predict the following: catch rates of various size classes of tuna, catch per set, and search time ($75K by U.S. in 1992 - see appendix B).

o Examine relationships between catch rates of yellowfin tuna by size with environmental data from regions other than the ETP ($60K by U.S. in 1992 - see appendix B).

Objective 1.5 Investigate the association of tunas and dolphins to determine if there are time periods when tunas can be caught in the vicinity of dolphin schools, but without having to chase and encircle the dolphins.

1.5.1 Approach -

The nature of the tuna-porpoise bond is still unclear, despite years of research. The relationship is thought to be food-based. Further, tunas are thought to follow dolphins. Therefore, it seems that tunas must be gaining some "advantage" in associating with dolphin in the ETP. Recent studies by the IATTC indicate that the relationship may not be constant over time. That is, the strength of the bond may vary by time of day. Information is needed on the behavior of the tuna-porpoise bond in the evening to evaluate the potential of locating tunas that are in the vicinity of, but not associated with, dolphins.

1.5.2 Rationale -

A better understanding of the biology of tunas and dolphins can be gained from tagging and behavioral studies. However, to understand the nature of the tuna-porpoise bond, studies must be performed on tunas and dolphins that are associated. If it is determined that tunas separate from dolphins under certain conditions, this information could be used to develop methods of fishing for tunas that do not involve chasing or

encircling dolphins.

1.5.3 Major Activities-

o Simultaneous tracking studies of tunas and dolphins ($165K by U.S. in 1992; additional funds available to charter purse-seine vessel - see appendix C).

o Behavioral studies of tuna-dolphin associations using visual techniques. Potential study areas include the near shore waters of Hawaii and the eastern Atlantic (no funds available).

o Behavioral studies of dolphins using satellite telemetry (no funds available).

Objective 1.6 Determine the food habits of tunas unassociated with dolphins and the food habits of tunas and dolphins that are associated. Use this information to determine if there are any prey items that could be used improve the efficiency of locating and capturing yellowfin tunas in the ETP that are not associated with dolphins.

1.6.1 Approach -

It has been suggested that the association between tunas and dolphins in the ETP is food-based. However, very little information on the food habits of ETP dolphins has been collected. Given the variety of possible interaction mechanisms between tunas and dolphins, better information on the dietary characteristics of tunas and dolphins should be investigated to determine if the location and distribution of certain prey items could be used to predict the distribution of large yellowfin tuna that are not associated with dolphins.

1.6.2 Rationale -

Dietary habits of tunas and dolphins vary by season, year, and area. Information on short- and long-term food habits of these animals is needed to evaluate the extent to which the diets of tunas and dolphins overlap. If there are specific prey items that are commonly utilized by tunas but not dolphins, this information could be used to improve the fishermen's ability to locate large yellowfin tuna in the ETP.

1.6.3 Major Activities-

o Determine the composition of prey in the stomachs of tunas and dolphins that are associated and the composition

of prey in tunas not associated with dolphins ($83K by U.S. in 1992 - see appendix D).

o Compare the types of prey tunas and dolphins utilize with radio-isotope techniques. This analysis provides a long-term perspective of trophic relationships and will complement the short-term perspective gained by looking at stomach contents ($83K by U.S. in 1992 - see appendix D).

o Determine the distribution of the major prey species of large yellowfin tuna and how these distributions are affected by environmental factors (no funds available).

Objective 1.7 Evaluate other approaches for locating tunas that are not associated with dolphin in the ETP.

1.7.1 Approach -

Fishermen currently use dolphins and birds as cues to locate schools of large yellowfin tuna. If dolphins are no longer used as cues, detection rates will decline unless alternative approaches to locating tuna schools are developed. In addition to evaluating the potential of the approaches described in this section, other approaches should be identified and considered.

1.7.2 Rationale -

To date, information to predict the location of large yellowfin tuna in the ETP or to improve the detection rate of tunas not associated with dolphin has not be systematically reviewed. Such an undertaking is warranted at this time.

1.7.3 Major Activities-

o Develop and test a set of hypotheses concerning factors that determine the distribution and abundance of large yellowfin tuna in the ETP (no funds available).

Objective 1.8 Evaluate the various approaches and implement field trials for those approaches that are likely to result in catch rates of tuna that are economically feasible .

1.8.1 Approach -

Once most or all of the preceding objectives have been met, an evaluation of the various approaches must be conducted. It is unlikely that all of the approaches will have similar

characteristics for catch rates by size, search time, and economic value of the load. For those approaches that are likely to prove economically feasible, at-sea trials should be designed and implemented.

1.8.2 Rationale -

Dolphin-safe methods of fishing that produce tuna at a rate and of a size where costs exceed gross profits will not contribute to the resolution of this problem. To date, alternative fishing methods have not been demonstrated to be economically feasible.

1.8.3 Major Activities-

o Field test one or more alternative fishing methods (no funds available).

o Determine the "economic window" for fish production (e.g., expected catch rates by gear type, expected costs, etc.) for tuna in the ETP (no funds available).

Objective 1.9 Compare by-catch rates of non-target marine species (e.g., other tunas, undersized tunas, sharks, birds, turtles, and cetaceans) for all proposed alternative fishing methods to by-catch rates of "porpoise" fishing for tunas in the ETP.

1.9.1 Approach -

Dolphin-safe methods of fishing that result in unsustainable catch rates of other non-target species should not be considered acceptable. Prior to replacing "porpoise fishing" for tunas with other methods, an analysis of by-catch rates should be performed.

1.9.2 Rationale -

Almost all fisheries catch non-target species to some extent. Replacing the by-catch of dolphin with catches of other non-target species is not a solution. Preliminary information on by-catch (at least to type of animal) by gear types being considered for use in the ETP is available. To date, these data have not been compiled in a comprehensive manner.

1.9.3 Major Activities-

o Prepare a report on catch rates by size of target species and by-catch rates of non-target species for the following gear types and fishing practices: school fishing with purse seines, log fishing with purse seines, fishing on

FADs with purse seines, school fishing with trawls and paired-trawls, fishing with long-lines, and fishing with bait-boats (no funds available).

GOAL 2. DEVELOP AND EVALUATE METHODS OF PURSE SEINE FISHING FOR TUNAS THAT INVOLVE CHASING BUT NOT ENCIRCLEMENT OF DOLPHINS

Using dolphins as cues to locate large yellowfin tuna, but then separating the tuna and dolphins prior to encirclement, would eliminate dolphin mortality and still allow the fishery to target large yellowfin tuna. There is anecdotal evidence from bait-boat fishermen that tunas will separate from dolphin to feed on bait for a period of 10 - 20 minutes. Additional or different stimuli may cause the bond to break for longer periods of time or at least over a greater distance. One disadvantage of this approach is that the act of chasing dolphin schools with speed boats to herd them back to the purse seine vessel and to aggregate the tunaS may be disruptive to the dolphins. At present there is no information pertaining to this problem.

Objective 2.1 Investigate the association of tunas and dolphins and determine if there are time periods when tunas can be caught in the vicinity of dolphin schools, but without having to encircle the dolphins.

2.1.1 Approach - (see 1.5.1)

2.1.2 Rationale - (see 1.5.2)

2.1.3 Major Activities- (see 1.5.3)

Objective 2.2 Determine the food habits of tunas unassociated with dolphins and the food habits of tunas and dolphins that are associated. Use this information to determine if there are prey items that would cause tunas to disassociate from the dolphins temporarily .

2.2.1 Approach - (see 1.6.1)

2.2.2 Rationale - (see 1.6.2)

2.2.3 Major Activities- (see 1.6.3)

Objective 2.3 Develop and evaluate the potential utility of acoustic, visual, and chemical stimuli to separate tunas and dolphins that are associated.

2.3.1 Approach -

Over the last 15 years, many attempts have been made at trying to separate tunas and dolphins prior to encirclement using various stimuli (positive and negative). However, much has been learned about negative and positive conditioning over the last 15 years and many of the earlier attempts were confounded by a lack of experimental rigor.

2.3.2 Rationale -

Prior attempts to separate tunas and dolphins typically used a single stimulus (e.g., acoustic play back) and experiments were generally performed near the vessel (often inside the purse seine). Therefore, conclusions from these studies may not be definitive. Information is not available concerning the effectiveness of using multiple stimuli remote from the purse seine vessel to separate tunas and dolphins long enough to allow the tunas to be encircled without encircling the dolphins.

2.3.3 Major Activities-

o Design and implement an experiment to test the effectiveness of combinations of visual, chemical, and auditory stimuli in separating tunas and dolphins prior to encirclement (no funds available).

Objective 2.4 Develop and evaluate other methods of separating tunas and dolphins that are associated.

2.4.1 Approach - (see 2.3.1)

2.4.2 Rationale - (see 2.3.2)

2.4.3 Major Activities- (see 2.3.3)

Objective 2.5 Evaluate the various approaches and implement field trials for those approaches that are likely to result in catch rates of tuna that are economically feasible .

2.5.1 Approach - (see 1.8.1)

2.5.2 Rationale - (see 1.8.2)

2.5.3 Major Activities- (see 1.8.3)

Objective 2.6 Compare by-catch rates of non-target

marine species (e.g., other tunas, undersized tunas, sharks, birds, turtles, and cetaceans) for all of the proposed alternative fishing methods to by-catch rates of "porpoise" fishing for tunas in the ETP.

2.6.1 Approach - (see 1.9.1)

2.6.2 Rationale - (see 1.9.2)

2.6.3 Major Activities - (see 1.9.3)

GOAL 3. IMPROVE THE EXISTING METHODS OF PURSE-SEINE FISHING FOR TUNAS ON DOLPHINS SUCH THAT MORTALITY RATES ARE BETWEEN 0.0 AND 0.5 DOLPHINS KILLED-PER-SET ON AN ANNUAL BASIS FOR THE INTERNATIONAL FLEET

The annual incidental mortality of all dolphins caused by the purse seine fishery for tunas in the ETP since 1973 has varied between 13,493 animals and 264,973 animals. Over the last five years the mortality rate for the international fleet has decreased considerably. In 1991 the mortality rate of the international fleet was approximately 3.2 dolphins killed-per-set (KPS). The fleet with the lowest mortality rate in 1991 was Vanuatu (1.75 KPS). In 1992 mortality rates for several of the fleets are less than 1.0 KPS. Over the past several years approximately 10,000 dolphin sets per year have been made. Therefore, it should be possible to get total mortality to less than 10,000 dolphins per year in the very near future. Additional improvements in gear and procedures over the next 12 months are possible and should be pursued. It should be noted that most of the dolphin mortality is associated with a relatively small number of problem sets. Therefore, even small improvements in fishing practices that would reduce the number of problem sets per year could result in considerable reductions in dolphin mortality.

Objective 3.1 Evaluate the following in terms of their potential for reducing the percentage of problem sets: 1) use of Acoustic Doppler Current Profilers to detect subsurface currents, which are associated with "net-collapse"; 2) use of the "Medina double cork line" to reduce entanglement; 3) use of jet boats to free entangled dolphins from the net; 4) use of different types of net materials, cable materials, hang-ratios, and "cork-lines" to reduce the incidence of roll-ups and net collapse; 5) the utility of other approaches to reducing dolphin mortality associated with purse-seine fishing for tunas in the ETP.

3.1.1 Approach -

Approximately 80% of dolphin mortality is associated with 20% of the sets. The two most common problems associated with these sets are net collapse and canopy formation. Either can be associated with gear malfunctions, sea state, subsurface currents, and skipper proficiency. Small improvements in materials and dolphin-rescue equipment could reduce the number of problem sets, which could dramatically reduce dolphin mortality.

3.1.2 Rationale -

Several recommendations from experienced skippers and engineers concerning improvements in existing purse seine technology have been made, but little has been done to evaluate their effectiveness in reducing dolphin mortality. Governments working with their fleets must coordinate tests of various equipment and fishing practices. Further, regular meetings to discuss the results of at-sea trials are needed to distribute information on what does and does not work.

3.1.3 Major Activities

- o Conduct at-sea trials of Current Profilers for identifying conditions where subsurface currents are likely to cause net collapse (no funds available).

- o Conduct at-sea trials with nets configured with double cork lines. Compare mortality rates from modified nets with existing nets, after an adequate number of test sets have been made on dolphins (no funds available).

- o Conduct additional at-sea trials where jet-boats are used to herd dolphins away from net canopies and out of the net during backdown. Compare mortality rates from sets where jet-boats were used with sets where jet-boats were not used ($$ from Mexico available in 1992).

- o Conduct at-sea trials of improved methods for hand releasing dolphins (no funds available).

- o Contract and consult with gear and fishing experts concerning ways to improve existing methods of fishing for tunas in the ETP ($$ from Mexico available in 1992).

- o Convene a workshop of engineers and gear specialists to make recommendations concerning net materials, cable materials, hang-ratios, and methods of reducing cable twist and other means of reducing the probability of net roll-ups and canopy formation (no funds available).

o Conduct at-sea trials of recommendations generated by the workshop listed above (no funds available).

Objective 3.2 Determine the extent to which fishing practices for tunas in other regions result in cetacean mortality.

3.2.1 Approach -

Associations of tunas and dolphins have been reported from many areas of the worlds oceans. The ETP seems unique in that the association is so strong that tuna can be caught by chasing and encircling herds of dolphins. However, in other oceans tuna-dolphin associations have also been used by fishermen to locate and capture tuna. Further, cetaceans in general have been reported to associate at a low rate with logs and other floating objects that are used by fishermen to locate and capture tunas with purse seines. However, to date a comprehensive review of the available data has not been published. These data will be used to determine if log fishing and school fishing practices in other areas where dolphin mortality is presumed to be low could be adapted to the ETP.

3.2.2 Rationale -

During the recent IATTC-sponsored workshop on the association of tunas with floating objects, a great deal of discussion centered around the association of tunas and dolphins in the ETP and other regions. The proceedings of this workshop should provide a valuable summary of much of the information that is currently available. However, during the workshops, several additional sources of information were identified and several analyzes of the available data were suggested that have not been completed to date.

3.2.3 Major Activities -

o Follow-up on as many of the recommendations from the recent IATTC workshop on tunas and floating objects as possible (no funds available).

o Where possible, determine the number of cetaceans that are encircled per year and the number of marine mammals that are killed per year in the different purse seine fisheries for tunas in regions other than the ETP (no funds available).

o Compare fishing practices, catch rates, dolphin mortality rates, and other by-catch rates from these fisheries with the ETP purse seine fishery and prepare a summary report (no funds available).

Objective 3.3 Develop and evaluate an international program directed at 1) educating skippers about new developments in purse-seine fishing on dolphins, 2) establishing a skipper performance system under which skippers with unacceptable dolphin-kill rates are either trained or removed from the fleet, and 3) establishing a temporary quota for the international fleet (e.g., 10,000 animals), with the goal of ratcheting this quota to zero over a fixed period of time. Establish a schedule of annual or bi-annual meetings to review progress in achieving the overall goal of eliminating dolphin mortality, while maintaining high yields of tuna in the ETP.

3.3.1 Approach -

The IATTC convened a special meeting in Costa Rica in September 1990 to develop a program to reduce dolphin mortality. An additional meeting was held in January 1991 in San Diego. However, to date a binding resolution or agreement has not been forthcoming with the member nations of the IATTC concerning the management of dolphin mortality associated with purse seining for tunas in the ETP. An international solution is necessary to resolve this issue.

3.3.2 Rationale -

The current situation has led to several nations being embargoed by the U.S. This creates a disincentive for nations to continue to cooperate with the IATTC in resolving the tuna-porpoise problem and in the long-term may disadvantage the dolphin stocks. Eliminating "porpoise fishing" without developing alternative methods of fishing for tunas will likely cause tuna stocks to be disadvantaged and will likely disadvantage other predators, such as sea turtles, sharks, sea birds, and other species of cetaceans. The reaction of any one country to the development of a comprehensive management program by the member nations of the IATTC is not the primary issue. The primary issue should be the development of a management approach that utilizes target species efficiently and minimizes to the greatest extent possible the mortality of non-target species. There should be no situations where the taking of individuals from a particular population is not sustainable or where such removals will disrupt the way in which the ETP ecosystem functions.

3.3.3 Major Activities

o Establish a schedule for meetings to review progress in improving existing methods and new methods of fishing for tunas in the ETP (no funds available).

o Establish a temporary quota on dolphin mortality for the remainder of 1992 and 1993.

o Establish international skipper performance standards.

GOAL 4. DEVELOP AND EVALUATE METHODS OF FISHING FOR TUNAS OTHER THAN PURSE-SEINING

Several recommendations concerning the possibility of fishing for tunas with methods other than purse seines or augmenting the existing market for tunas caught in the ETP to something other than a canned product have been proposed. However, an evaluation of the economic feasibility of such approaches has not been performed to date.

Objective 4.1 Evaluate the potential utility of fishing tunas in the ETP with paired trawls, long-lines, or other methods.

4.1.1 Approach -

If alternative methods of fishing for tunas in the ETP could be developed that did not involve purse seines, dolphin mortality would likely be eliminated. However, not all alternative methods are "dolphin-safe". An evaluation of the potential for locating and catching tunas at a rate that is economically practical is needed before such an approach can be seriously considered.

4.1.2 Rationale -

Information from areas outside the ETP should be compiled and gathered concerning tuna catch rates, size distributions, search times, etc. Based on these data, an evaluation of the economic feasibility of these approaches can be made.

4.1.3 Major Activities- (see 1.8.3)

o Evaluate the effectiveness of various baits to attract large yellowfin tuna ($$ from Mexico in 1992).

o Evaluate the potential for using paired-trawls or long-lines to capture large yellowfin tuna at rates comparable to existing methods of fishing (no funds available).

Objective 4.2 Compare by-catch rates of non-target marine species (e.g., other tunas, undersized tunas, sharks, birds, turtles, and cetaceans) for all of the proposed alternative fishing methods to by-catch rates of "porpoise"

fishing for tunas in the ETP.

4.4.1 Approach - (see 1.9.1)

4.4.2 Rationale - (see 1.9.2)

4.4.3 Major Activities- (see 1.9.3)

Appendix A. A proposal to investigate the feasibility of locating tuna not visibly associated with dolphins or other surface cues utilizing an airborne light detecting and ranging device (LIDAR).

cost: $80K in 1992

ROPOSAL TO INVESTIGATE THE FEASIBILITY OF LOCATING TUNA NOT BLY ASSOCIATED WITH DOLPHINS OR OTHER SURFACE CUES UTILIZING AIRBORNE LIGHT DETECTING AND RANGING DEVICE

RODUCTION:

a result of the recent reauthorization of the Marine Mammal ection Act, the SWFSC is responsible for developing means of cing or eliminating the incidental take of dolphins involved he eastern tropical Pacific (ETP) tuna purse seine fishery. goal would be accomplished by eliminating the encirclement of hins. Increasing the ability of tuna purse seine fishermen to te yellowfin tuna schools when they are not associated with hins has potential for reducing cetacean involvement in fishing ations.

GROUND:

reat deal of effort to develop techniques for probing of the ronment with laser technology has been made since the advent he laser. A light detecting and ranging device (LIDAR) uses ser to generate a short pulse of light. As the pulse of light els through the atmosphere or water, backscattered light is ected by a receiving telescope, then collimated, filtered, sured and recorded. Vertical probing of the atmosphere with a R has been used to detect clouds and aerosol layers (Fioco and s, 1964). Downward-directed LIDAR has been used as a bathymeter ic, Sizgoric and O'Nell, 1987). Airborne LIDAR systems can ile sub-surface schools of pelagic fish (Squire and Krumboltz, .), and may be useful for species identification as well rnside and McGillivary, 1991).

excessive size and weight of earlier systems limited ication of airborne LIDAR to commercial fishing operations. spotters generally use single engine fixed wing aircraft, or, in the tuna purse seine fishery, small helicopters. Recent elopments in solid-state lasers and small computer systems have ed this weight problem.

September, 1990 Remote Sensing Industries (RSI), Inc. of tham, Massachusetts produced an airborne LIDAR. The total ght of all components of the prototype LIDAR system is 245 ds. The system has been designed to fit in the aft passenger of a Bell Jet Ranger helicopter, a model which is currently aboard many of the U.S. flag tuna purse seiners.

LIDAR prototype was installed in a helicopter borrowed from a seiner owned by Caribbean Marine Service Co., Inc. of San o, California. Test flights with the LIDAR were made in May September, 1991 over the coastal waters off southern fornia. Attempts were made to detect the bottom contour and dentify schools of fish. Bottom contours and several profiles

schooling fish apparently were recorded successfully. Recorded a reinforced visual observations from the test helicopter cerning the presence or absence of fish. Absolute success is ertain because surface verification was not attempted in these liminary tests. A vessel with a means of measuring the depths ped and of verifying the quantity and identity of fish schools orded would be necessary in order to conduct adequate surface sub-surface verification of the LIDAR's capability to detect record the presence of schooling fish.

EARCH OBJECTIVES:

purpose of the proposed research is to explore the useful ication of an airborne LIDAR system for increasing searching ciency for tuna not associated with dolphins. Three main ications are to be tested:

Rapid assessment of logs from the helicopter.

rmine whether an airborne LIDAR provides enough useful rmation beyond the helicopter spotter's ability to visually rve surface or near-surface tuna, to avoid having the seiner ect the log for the presence of fish. (Helicopters commonly ch at a distance of 10-30 miles away from the seiner. Tuna e seine vessels travel at speeds of 11-15 knots.) The goal of test is to determine fish presence around a log, the amount fish, the depth of the school, the vertical and horizontal ments of the school; and, eventually, the type or size of fish ent.

Tracking of "schoolfish".

rmine whether a LIDAR-equipped helicopter can be used to track schools that dive and disappear from sight in areas of olfish activity, when visual sightings of finning or feeding vity at the surface are the only other cues available to the ermen. This would prove useful if most of the fish are elling underwater, only occasionally surfacing to feed. ing "on the fish" is of paramount importance to tuna fisherman, cially in areas of schoolfishing activity. Tuna that are not ssociation with floating objects or other surface-oriented als, such as dolphins, are often on the move and more difficult atch, as well as difficult to relocate once lost. Again, the ity of an airborne LIDAR to indicate the presence and abundance ish, depth of schools, and horizontal and vertical movements chools are the goals of this test.

Supplement conventional searching efforts.

rmine whether a LIDAR-equipped helicopter can enhance the ine daily searching activity of tuna purse seine vessels. The ity of an airborne LIDAR to detect sub-surface fish, fish that

ight be overlooked because of little or no bird activity, or fish t the surface in times of poor sighting conditions are the bjectives of this test.

ESEARCH METHODS:

esearch will consist of operating and evaluating an airborne LIDAR ystem during the various typical phases of searching, assessment nd setting operations aboard a tuna purse seine vessel.

.. Operate an airborne LIDAR over the net during pursing and net roll:

a. Determine if tuna can be visually identified on the computer monitor. We will be able to verify the presence, amount and species of fish present when the catch is loaded and compare with the LIDAR observations and data collected.
b. Determine if yellowfin, skipjack, sharks and other species produce a unique "signature" due to different reflective properties.
c. Determine if fish of different sizes produce different signatures.
d. Determine if the bottom of the net can be profiled. We can calculate or measure this depth and get an idea of how deep the laser penetrates in ETP waters.
e. Determine if the depth of penetration of the laser beam varies under different oceanographic conditions (i.e., effects of differences in water clarity, effects of glare, effects of surface wind).

2. Operate an airborne LIDAR over logs before and after a set:

a. Determine if LIDAR data are comparable to, more efficient than, or less efficient than sonar data collected aboard the seiner; compare catch results with pre-set data collected.
b. Determine if different species and sizes of fish produce different signatures which can be used in pre-set assessments.
c. Determine, in consultation with the skipper, if time was saved by use of the LIDAR vs. waiting for the fish to show visually on the surface.
d. Determine, in consultation with the skipper whether using the LIDAR system led to a set that would not otherwise been made due to a lack of information.

3. Operate an airborne LIDAR over areas of schoolfish:

a. Determine whether schools of tuna can be tracked as they dive.

b. Determine, in consultation with the skipper, whether using the LIDAR led to a set that would not otherwise have been made.
c. Determine, in consultation with the skipper, whether LIDAR data indicated a larger body of sub-surface fish than was suggested by surface observations.

. Operate an airborne LIDAR system while randomly searching:

a. Determine, in consultation with the skipper and spotter, whether use of the LIDAR led to detection of tuna that would otherwise have been overlooked.
b. Determine whether differing oceanographic conditions warrant adjustment to the operation of the LIDAR system such as flying altitude, angle of laser beam direction and adjustments to the dimensions of the aperture in the receiving telescope.

XPECTED FUNDING REQUIRED:

ielding of LIDAR system aboard a working tuna purse seiner in the TP.....53k

fforts have been made towards fielding the airborne LIDAR prototype aboard a tuna purse seiner in the ETP. We have a commitment from a vessel owner to allow us to conduct field tests during fishing operations aboard his vessel. This is not a charter; we will not be paying for vessel days or use of the helicopter. We do need to provide funds for the "ruggedization" of the prototype for extended use on the high seas, the modification of the existing software to an operational version with simpler displays for easier interpretation, and so that the project engineer can accompany the vessel on this "maiden voyage" of the LIDAR system. It is expected that in-flight and post-flight adjustments to the laser, amplifier and other components of the system will be necessary in response to changing environmental conditions. Interpretation of data collected and general troubleshooting also dictate the presence of technical personnel. In addition, it will be necessary for a NMFS representative experienced in tuna purse seine operations to be aboard to coordinate activities and collect data on fishing success in relation to LIDAR data collection efforts. Projected costs include pre-cruise preparations and testing, travel expenses, salaries for 30-40 days at sea, and preparation of a final report by LIDAR project technical staff.

Fielding of LIDAR system aboard a chartered tuna purse seiner in

conjunction with other research efforts.....25k

Further testing and use of the LIDAR system in support of research on schooling tuna aboard a chartered purse seiner after the initial tests described above would require substantially less funding. Expenditures would be for preparation, shipping, travel expenses and salary for the engineer. If a different type of helicopter were used on the charter than on the preceding fishing trip, about 2k in additional funding would be necessary for modifications and installation.

SCHEDULE OF EVENTS:

February/March, 1992.....Field LIDAR prototype aboard tuna purse seine vessel for 30-40 days. (schedule depends on funding and availability of seiner)

May, 1992.....Analyze results of LIDAR testing and determine applicability to fishing efforts. Plan use of LIDAR system in support of research activities.

November, 1992.....Field LIDAR system aboard chartered tuna purse seiner for 30 days.

SUMMARY:

Tuna purse seine vessels operating in the ETP have traditionally relied on visual observations, i.e. birds, logs and dolphins to locate their targets. Dolphin indicators have historically been responsible for 60-90% of the eastern Pacific tuna catch annually. Methods for locating tuna when they are not associated with dolphins (e.g., at night , when they are travelling alone, or when they are far enough below the surface that they are not visible to a spotter) could reduce incidental dolphin involvement in fishing operations. Supplementing visual searching efforts with sub-surface electronic surveillance using airborne LIDAR could expand the effective searching field beyond the surface layer, would not be affected by the limits of visual acuity, has the ability to detect fish day or night, and could improve the economic efficiency of seiner operations in terms of time and fuel savings. We propose to test these ideas using a typical tuna purse seiner during typical fishing operations.

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Appendix B. Environmental predictors of yellowfin abundance, catchability and distribution.

cost: $135K in 1992

April 16, 1992

R. Punsly and P. Fiedler

Environmental Predictors of Yellowfin Abundance, Catchability and Distribution

Introduction

Section 110(a) of the Amendments to the Marine Mammal Protection Act of 1972, passed by Congress on 23 November 1988, stipulated identification of appropriate research into promising new methods of locating and catching yellowfin tuna without the incidental capture of dolphins. During the first quarter of FY 1992, Congress appropriated $750,000 for alternative (dolphin-safe) fishing techniques to be initiated with the above-mentioned funds during 1992. This proposal was among those reviewed and approved as worthy of funding by a scientific review panel convened by NMFS on 5 and 6 of March, 1992. Based on the fact that they have the most complete records of yellowfin catches and length frequencies in the eastern tropical Pacific (ETP), their extensive experience in analyzing both of these data sets, their ability as an organization to involve other members of the research community into a concerted effort, and their established record of working with other countries involved in the ETP purse-seiner fishery, the Inter-American Tropical Tuna Commission (IATTC) has been designated as the group to conduct the proposed research.

A report detailing the work performed and accomplishments made during the research will be provided to the Chief, Marine Mammal Division, Southwest Fisheries Science Center within one year of receipt of the environmental data (currently being prepared by Dr. Paul Fiedler) and computer equipment needed to conduct the research.

Proposed Research

Yellowfin abundance, catchability and distribution have long been presumed to be correlated with environmental factors such as thermal

structure, and perhaps salinity, wind speed and direction, oxygen levels, bottom depth, and primary production. We propose a collaborative study to investigate correlations between yellowfin catch rates and environmental factors in the eastern Pacific Ocean. Combining Dr. Fiedler's experience in analyzing and interpreting environmental data and Punsly's experience in analyzing and interpreting yellowfin catch rates, we will try to determine which environmental factors reflect abundance and the horizontal distribution or habitat of yellowfin and which factors reflect catchability or vertical distribution. Finally, we will look for environmental conditions in which large yellowfin are both abundant and available to non-dolphin purse-seiner fishing.

Environmental and catch rate data for 1970-1990 will be analyzed in at least two ways. A general linear model (GLM) approach will be used to estimate the effects of environmental factors on catch rates of both purse-seiners and longliners, catch per purse-seiner set and search times between sets. Canonical correspondence analyses (CCAs) will be used to determine which combination of environmental variables best explains the variations in catch rates. The advantage of the first method (GLM) is that catch rates are simultaneously standardized by set types, vessel speed and years, thus reducing the chances that the relationship between catch rates and environmental factors are confounded by these other factors. The advantage of the second method (CCA) is that the optimum non-linear combination of environmental variables can be determined. A combination of environmental variables found to be an optimum predictor of catch rates may be only a proxy for an unmeasured environmental parameter or process. We will use Dr. Fiedler's work on productivity, currents, and upwelling to interpret the predictor variables. Also, fine-scale MOPS environmental data may be useful for interpretation of the results; for example, daily temperature variance, which is an indicator of frontal and eddy structures, could be estimated. Finally, the methods will be applied to estimates of the catch rates of semi-annual age groups, with emphasis on determining good fishing areas for large yellowfin which are not associated with dolphins.

Suggested Methods and Estimated Time Frame

1) Fiedler will make a data set of temperature and wind data by 2°x2° quadrangle-bimonths for 1979-1988. At the same time, Punsly will try to get a larger data set from Steve Pazan and will try to obtain a data set on bottom depth. Also, Punsly will make summaries of standardized catch rates to be used in the CCAs. Fiedler and Punsly will make these data sets available to each other. Step 1 should be completed during May, 1992.

2) The effects of the environment on catch rates, catch per set and search times will be analyzed by Punsly for all sizes of fish combined using GLMs. This should take about one month.

3) The CCAs on all sizes of fish combined will be done by Fiedler (with help from Punsly and perhaps Steve Reilly if needed), this should also take about a month.

4) The catch rates of semi-annual age groups will be estimated from length-frequency and longline data by Punsly. This should take about 6 weeks.

5) Parts 2 and 3 will be repeated on semi-annual age groups. This will take approximately 2 months.

6) The results of part 5 will be used to find conditions conducive to high purse-seiner catch rates of non-dolphin associated large yellowfin. This should take 2 or 3 weeks.

7) Depending on the results from one to three manuscripts will be produced from the results. At least 2 weeks will be need to interpret results and first rough drafts should be ready about 1 month after that.

Proposed budget

1) Salaries (One part time temporary technician).....$15,000.

2) Equipment (High speed (>20 "MIPS") graphics workstation with 10MB memory, 500MB disk storage, floating point accelerator, 1280x1024 color monitor, serial and parallel ports, S-PLUS statistical software, fortran and C

compilers, networking software, additional graphics software, and color graphics printer.....$20,000.

All equipment purchased to conduct this study is accountable and will remain property of the National Oceanic and Atmospheric Administration; however, IATTC will have exclusive use of the above mentioned equipment for at least ten years from the time of purchase.

The Service will spend approximately $80K on salaries and $20K on equipment to assist the IATTC in the analysis of the ETP data and the analysis of tuna and oceanography data from regions outside the ETP.

Appendix C. Simultaneous tracking study of dolphins and tuna.

cost: $165K, plus the cost of a vessel charter, in 1992

SIMULTANEOUS TRACKING STUDY OF DOLPHINS AND TUNA

Introduction

Section 110(a) of the Amendments to the Marine Mammal Protection Act of 1972, passed by Congress on 23 November 1988, stipulated identification of appropriate research into promising new methods of locating and catching yellowfin tuna without the incidental capture of dolphins. During the first quarter of FY 1992, Congress appropriated $750,000 for alternate (dolphin-safe) fishing techniques to be initiated with the above-mentioned funds during 1992. This proposal was among those reviewed and approved as worthy of funding by a scientific review panel convened by NMFS on 5 and 6 March, 1992. Based on the background and past accomplishments of their staff, their ability as an organization to involve other members of the research community into a concerted research effort, and their established record of working with other countries involved in the eastern tropical Pacific (ETP) tuna purse-seine fishery, the Inter-American Tropical Tuna Commission (IATTC) has been designated as the group to conduct the proposed research.

Field work will take place in conjunction with available ship time aboard the NOAA research vessel *MacArthur*, November 3 through December 3, 1992. Field work aboard the *MacArthur* will be coordinated with efforts aboard a chartered tuna purse-seine vessel. Both vessels are critical to the successful completion of the proposed research.

A report detailing work performed and accomplishments made during the research will be provided to the Chief, Marine Mammal Division, Southwest Fisheries Science Center within 90 days of the completion of the fieldwork. All equipment purchased with these funds is accountable and will remain property of the National Oceanic and Atmospheric Administration, however the Inter-American Tropical Tuna Commission is guaranteed exclusive use of the equipment for at least ten years from the purchase date of the equipment.

Background

The nature of the tuna-dolphin bond is still unclear, despite the many years of research devoted to both tunas and dolphins in the eastern tropical Pacific Ocean (ETP). Yellowfin tuna (*Thunnus albacares*) are associated most frequently with spotted dolphins (*Stenella attenuata*), but are found with spinner dolphins (*S. longirostris*) and common dolphins (*Delphinus delphis*) as well. The overlap in the feeding habits of spotted dolphins and yellowfin tuna found by Perrin et al. (1973) suggests that the relationship may be food-based; however, the similarity in feeding habits could be a result, rather

may be food-based; however, the similarity in feeding habits could be a result, rather than the cause, of this association. Studies by the IATTC suggest that the relationship may be a diurnal one (Scott, 1991), although how these multi-species aggregations break up and re-form is not known completely.

A better understanding of the biology of the dolphins and tunas has been gained from tagging and tracking studies (Bayliff, 1979; Perrin et al., 1979; Carey and Olson, 1982; Holland et al., 1990), but these studies did not address the nature of the tuna-dolphin bond in the ETP. To study the relationship between these species, we propose to radio-track spotted dolphins and sonic-track yellowfin tuna from the same aggregation simultaneously. The use of pressure-sensitive transmitters on the tuna would also permit an analysis of the tunas' vertical distribution. This information would be valuable in two ways. On the scientific side, the study of tuna and dolphin movements and interaction, in conjunction with food-habits studies conducted by the IATTC and NMFS, will help to establish the longevity and dynamics of the tuna-dolphin bond and the degree that it is food-based. On the tactical side, we could determine whether the bond loosens at particular times or under certain conditions, and, if so, whether the tuna would be vulnerable to fishing at such times.

The spotted dolphin will be the primary dolphin species of interest. We will focus on the following questions: Does the dolphin-tuna bond break (or stretch) under particular circumstances, e.g. time of day, temperature, or oxygen stratification? When the tuna and dolphins are apart, where do the tuna go, at what depth do they swim, and how tightly do they school? When they are together, how are they oriented spatially? Do the tuna swim at different depths when they are associated with dolphins than when they are not?

We propose a preliminary study to capture dolphins and tunas from the same aggregation, attach transmitters to as many individuals of each species as is practical, release them, and monitor their movements and observe their behavior. A tuna purse-seine vessel will be chartered for capturing the animals. The dolphins and tuna will be tracked from the NOAA research vessel and from chartered purse seiner.

Study Area

The study area will be determined, in part, by the the timing of the cruise. The calmest weather during November is likely to be found within 250 miles of the coast of Costa Rica and Panama (from about the Golfo de Nicoya to Punta Mariato), between 90-100° W and 10-12° N (east of Clipperton), and within 200 miles of the Mexican coast off Acapulco (Forrest Miller, IATTC, pers. comm.; see Figure). Historically, the waters off Costa Rica and Panama are good for school sets and log sets during November, and the

waters off Acapulco and east of Clipperton are good for dolphin sets (Hall et al., unpub. ms.).

Permits

It will be necessary to apply for a U.S. permit to capture and tag the dolphins. Michael Scott will prepare the permit application and submit it to NMFS in April. Depending on the area selected for the study, it may be necessary to solicit permits from Mexico, Costa Rica, and Panama as well. The IATTC will apply for these permits.

Research Vessel Shiptime

Thirty days of shiptime will be available aboard the R/V *MacArthur* during November-December 1992 (of which 7-10 days will be in transit from the study area to San Diego). Two advantages of the *MacArthur* are that it will be in the study area (off Costa Rica) in August-October, so deadhead time will be reduced, and it has two hydrographic launches (reportedly about 27 ft. long) that can be used for tracking. The ship has space for about nine scientists, and has oceanographic technicians and personnel to drive the tracking launches. The hydrographic launches carry 24-kHz and 100-kHz sonar, allowing the detection of fish schools below the boat. NMFS is checking into the possibility of installing bird radar and side-scan sonar on the *MacArthur* and scanning fishfinders for the launches.

Purse-Seine Charter

A purse seiner (most likely from the U.S. fleet) will be chartered for the same 30-day period to capture tuna and dolphins. It is important to have the constant capability to capture new animals throughout the study period to maximize the number of replicate experiments. While the tracking is being conducted, the seiner's helicopter will help track the dolphins and make aerial observations of the behavior and group dynamics of the dolphins and tuna. When not needed for the tracking experiment, the seiner can engage in other studies, particularly the sampling of stomachs and tissues from tunas, sharks, and other fish caught on logs and in unassociated schools to study the trophic structure of pelagic predator communities. We would use the stomach-content analyses and biomagnification techniques described in the Food Habits proposal.

We would require a purse seiner that has a helicopter and space available for the scientific party (up to 5 scientists, depending on the requirements of the ancillary projects).

Outfitting Research Vessels

We should order telemetry gear at least by late April and install the equipment when the *MacArthur* is in Seattle (until 7 May) or when it is in San Diego prior to the ETP cruises (20-30 July). We will install radio- and sonic-tracking equipment on the two hydrographic launches (see Holland et al., 1985), and radio-tracking gear aboard the *MacArthur* and the purse seiner (the larger vessels will carry spare sonic-tracking equipment, but no pre-cruise installation is anticipated at this time). On the launches, a mount for the hydrophone will be welded to the side of the launch and a mount for a 17-ft. antenna mast. On the *MacArthur*, a four-antenna array (Yagi-Uda antennas oriented at 90°-intervals) will be mounted above the mast. Ideally these antennas should be well away from the radar beam and 12 ft. away from other antennas or metal. The sonic- and radio-receivers require 12V power. We may also test an AN-TAS6 thermal imager (requiring 28 V) for locating birds, tunas, or dolphins at night. Any equipment necessary for tagging the tuna (e.g. tagging cradles) will be installed beforehand on one of the launches.

Tagging Tuna

The tuna will be captured prior to the backdown procedure. The tuna will be caught by handlining inside the net; if that option fails we will abort the tagging operations, release the dolphins using the backdown procedure, and bring the tuna aboard the seiner (stomachs from a sample of these tuna will be collected for food-habits study). Large fish will be drawn alongside one of the launches and lanced in the dorsal musculature with a spaghetti tag-sonic transmitter package (Bayliff and Holland, 1986). We may tag smaller tuna using the suture method described in Carey and Olson (1982) and Holland et al. (1985). The fork length of the tuna will be measured or estimated from marks along the launch's side. After tagging and measuring, the leader from the handline will be cut and the fish allowed to swim free inside the net until the entire tuna-dolphin aggregation is released as simultaneously as possible. We will tag as many of the tuna as practical in the time available (probably 2-5 individuals).

We will use 50-kHz ultrasound transmitters (VEMCO in Halifax, Nova Scotia) that have a nominal longevity of 3 days with an operating range of 0.8 miles (Holland et al., 1985; Bayliff and Holland, 1986). Transmitters with greater longevity and less range (22 days and 0.5 miles) may be used as well, although it is anticipated that having a greater range will be more important than greater longevity. At least two of these transmitters during each set will transmit information about ambient pressure to monitor the animal's swimming depth.

Tagging Dolphins

The dolphins will be caught by hand from inflatable rafts either prior to or during backdown. The dolphins will be outfitted with radio transmitters (Telonics in Mesa, Arizona) mounted on fiberglass plates that will be attached to the dorsal fin with two 1/4-in. delrin pins (Mate, 1989; R. Wells, pers. comm.). The delrin pins will be secured by magnesium nuts that corrode in sea water, releasing the package (in days or a few weeks). The tissue plugs removed to attach the package will be saved for genetic analysis. The length and sex of the dolphins will be recorded and the dolphins will be released inside the net so that the entire aggregation can be released together. The seiner's speedboats can be used to keep the net open and lessen the risk of net collapse.

It may be feasible to attach a time-depth recorder on the dolphin transmitter package. This device would record the diving behavior of the dolphins, which could then be compared with the vertical movements of the tuna. In order to recover the data, however, we would need to recapture the dolphin and remove the package.

Release

The entire tuna-dolphin aggregation will be released from the net together, preferably by releasing the ortza to open the net; if that is not practical, then we will continue the backing down until all the animals are released. We will position the launches prior to the release along the anticipated escape route of the aggregation. The purse seiner's helicopter will be launched to observe the behavior of the dolphins and tuna (particularly during and after release) and to help radio-track the dolphins during at least the first day.

Tracking

One launch will be primarily dedicated to tracking dolphins, the other will primarily track the tuna. Both will be rigged with both radio and sonic-tracking gear so that we can triangulate positions easier. The strategy will not be to attempt to track all animals simultaneously, but to focus on single animals, collecting data on other animals on an opportunistic basis or as a backup when signals from the focal animals are lost. If signals are lost from all the tuna, we will attempt to maintain contact with the dolphin herd(s) so as to determine if the dolphins and tuna reunite. The more tuna that are tagged, the more certain we will be that indeed no tuna from the original school are present when we hear no sonic transmissions near the dolphins. The tracking launches will attempt to get as close as possible to the dolphins and tuna without disturbing their behavior. We will record the behavior of the tagged dolphins and their herdmates, and monitor changes in herd size during the day. Of particular interest will be times when the dolphins and/or tuna are feeding (as indicated by visual observations, diving patterns from the telemetry data, and the presence of feeding birds). The presence of

other cetaceans and birds in the area will be recorded. Fish-finding sonar could be used, if not aversive to the dolphins, to locate the tuna school and prey schools in the area.

Because spotted dolphins typically spend only one second at the surface, they will be very difficult to determine a heading using a single handheld antenna. An automatic direction finder (ADF) connected to the receiver should allow us to get a rough bearing to the signal. (If the ADF system does not function well, we will monitor simultaneously stereo headphones two receivers connected to two of the four antennas. This will allow the operator to judge the relative loudness from any two antennas of the same signal, and by switching the antenna inputs, quickly make fore-aft and port-starboard decisions.)

The *MacArthur* will be used to coordinate the launches and helicopter, radio-track, collect oceanographic data, and serve as the mother ship for the launches. If needed, we may try to sonic-track from the *MacArthur* as well. Ship noise and lack of manuverability may make this difficult, but we can launch a small boat to get the receiving hydrophone away from the *MacArthur*. A small boat will also be used to shuttle relief crews to the launches. We will attempt to launch CTDs and seacats every hour when the ship is drifting to sample the oceanographic varibles on a fine-scale in order to relate them to the movements of the tuna and dolphins.

We will attempt to track for up to 3 days (the nominal battery life of the sonic transmitters). Following the first track, 2-3 more replicates will be attempted, depending on weather, time available, and crew fatigue. One of these replicates could be attempted with the greater-longevity sonic transmitters if a longer track is desired. We anticipate 6- to 8-hr crew shifts for the teams aboard the launches. On board the *MacArthur*, we expect that the tracking and coordination can be handled by one scientist with support from the normal shipboard watch. It is likely that an oceanographic technician will be required on duty as well.

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TRACKING BUDGET

Radio-tracking equipment	33K
Sonic-tracking equipment	37K
Camera equipment	6K
Miscellaneous equipment and installation costs	13K
Contract - Kim Holland and graduate student	8K
Travel and perdiem	15K
Seapay and overtime	15K
Miscellaneous expenses	6K
TOTAL	133K*

* The Service (NMFS) will spend approximately $32K on this project. These funds will cover travel costs for NMFS personnel, per-diem, and seatime.

Appendix D. Food habits of tunas and dolphins.

cost: $166K in 1992

FOOD HABITS OF TUNAS AND DOLPHINS

Introduction

Section 110(a) of the Amendments to the Marine Mammal Protection Act of 1972, passed by Congress on 23 November 1988, stipulated identification of appropriate research into promising new methods of locating and catching yellowfin tuna without the incidental capture of dolphins. During the first quarter of FY 1992, Congress appropriated $750,000 for research leading to alternate ("dolphin-safe") fishing techniques to be initiated during 1992. This research proposal was among those reviewed and approved as worthy of funding by a scientific review panel convened by NMFS on 5 and 6 March, 1992.

The Inter-American Tropical Tuna Commission (IATTC) is designated to conduct this study due to its established record of research on tuna and dolphins in conjunction with the countries that fish for tunas in the eastern Pacific Ocean and due to its special access to sample collection. The IATTC is the only organization that places international observers aboard tuna purse seiners to collect data at sea. The ideas and concepts of this research were originated by scientists at IATTC.

A progress report detailing work performed and accomplishments made during this research shall be provided to the Chief, Marine Mammal Division, Southwest Fisheries Science Center on or before 1 year after initiation of the project. A final report shall be provided on or before 2 years after initiation of the project. Initiation of the project shall take place when a suitable scientist is hired and in place at IATTC's headquarters in La Jolla. The IATTC shall undertake this project only if an adequate scientist is acquired.

Proposed Research

It has been suggested that the association between tunas and dolphins in the eastern Pacific Ocean (EPO) may be food-based (Perrin 1968, Perrin et al. 1973). An opinion common among people who have observed tuna-dolphin aggregations at sea is that the tunas follow the dolphins and not vice-versa (e.g. Allen 1985, cf. Au and Pitman 1986, 1988). If so, there must be an advantage to tunas to associate with dolphins. A popular hypothesis is that the dolphins' echolocation capabilities give them an advantage over tunas in finding food, and that by following the dolphins the tunas improve their probability of encountering food in the open ocean (Allen 1985). However, the tuna-dolphin association is not obligatory. Given the variety of possible interaction mechanisms that may be operating separately or in combination (Hammond 1981), the dietary characteristics of tunas and dolphins within and outside the aggregation need to be thoroughly investigated to better understand the nature of the bond in the EPO.

Another hypothesis is that the tuna-dolphin bond provides one or both species a measure of protection from predators. Likely predators would include sharks, small toothed whales, and billfishes (Scott 1991). Dolphins may cooperate to drive off sharks (Perrin 1968), and the protective advantage of schooling may be enhanced by the formation of large multi-species

aggregations. Sharks and billfishes are common in the EPO tuna fishing grounds. Silky sharks (*Carcharhinus falciformis*) share some of the same prey as yellowfin tuna (*Thunnus albacares*) (Mearns et al. 1981, Olson and Boggs 1986), and may be important predators of yellowfin and skipjack tuna (*Katsuwonus pelamis*). Previous studies indicated that silky sharks occupied a considerably higher trophic position than yellowfin and skipjack in the EPO (Mearns et al. 1981, Rau et al. 1983). If the overlap in food habits between yellowfin and spotted dolphins described by Perrin et al. (1973) represents competition, then predation on yellowfin and on the major components of yellowfin's diet would also affect the dolphin stocks and perhaps the strength of the tuna-dolphin bond as well. A study of the food inter-relationships of large EPO predators should include not only yellowfin and dolphins but also the other associated sympatric predators to better understand the role of community-level trophic interactions. No such studies of the pelagic predatory fishes co-occurring with tunas have yet been conducted in the EPO.

This study is designed to elucidate the trophic relationships between dolphins, yellowfin tuna, and other upper-level predators in the EPO at two time scales. The analysis of stomach contents will provide information on diet overlap and resource partitioning at the time of sampling. Stable carbon and nitrogen isotope constituents in the tissues give a longer-term representation of trophic level.

Stomach Content Analysis

Despite many years of research on tunas and dolphins in the EPO, only one study has been published on the food habits of these animals caught in unison. Perrin et al. (1973) described the stomach contents of 79 yellowfin tuna, 140 spotted dolphins (*Stenella attenuata*), and 46 spinner dolphins (*S. longirostris*) taken from 6 net hauls during April 1968 in a narrow geographical area. Only one sample was taken in the early morning and none in the late afternoon. This limited sample size was not adequate to interpret the feeding inter-relationships between yellowfin and dolphins over time and space in the EPO. By expanding this study, we plan to collect specimens of a wider size range, throughout the daylight hours, from more areas, and from a greater number of species. We will also sample the communities that aggregate around logs and other floating objects.

A stomach content study alone is not sufficient to determine diet overlap of tuna and dolphins. Associated yellowfin, dolphins, and seabirds that form the target of purse-seine sets in the EPO are feeding aggregations, and stomach contents taken from these sets are expected to be comparable. Previous studies have not addressed the key issue: do yellowfin and dolphins prefer the same prey, or are the stomach contents from associated animals comparable because they are caught in the same place at the same time. In other words, is the diet overlap described by Perrin et al. (1973) a consequence rather than the cause of the association? In this study, stomachs will also be sampled from the yellowfin and other fishes caught in sets not involving dolphins. Unfortunately, unassociated dolphins will not be available for study, and neither the tunas nor dolphins can be sampled at night. Therefore, a second independent indicator of diet overlap is needed. Stable carbon and nitrogen isotopes in the animals from a few sets will be analyzed to determine the feasibility of this approach.

Carbon and Nitrogen Isotope Ratios

Biomagnification of certain chemical and isotope constituents of animal tissues provides a popular means of measuring trophic position and energy pathways in communities. Ratios of stable carbon and nitrogen isotopes are known to undergo biomagnification in the food web. It has been shown that the $^{13}C/^{12}C$ ratio ($\delta^{13}C$) of animal tissues is significantly elevated relative to that of the diet (McConnaughey and McRoy 1979, Fry and Sherr 1984). If a community of several animal species existed such that one species was the sole prey of the second species, and the second species was the sole prey of a third species, and so on, a progressive increase in animal $\delta^{13}C$ would be expected, paralleling the ascent to higher trophic levels. In nature, feeding behavior and trophic structure within animal communities is usually more diverse and complex than this simple food-chain model (Pimm 1982). Still, systematic increases in animal $\delta^{13}C$ as a function of estimated trophic level in marine communities have been reported (McConnaughey and McRoy 1979, Rau et al. 1983, Fry and Sherr 1984). Biomagnification of $\delta^{13}C$ is related to the fractionation of assimilated carbon: animals selectively respire ^{12}C (DeNiro and Epstein 1978).

Evidence of trophic position of some principal members of the epipelagic eastern tropical Pacific Ocean (ETP) ecosystem has been obtained in recent years using stable carbon isotopes and chemical indicators of biomagnification. Mearns et al. (1981) found good correlation between the ratio of Cs/K in muscle tissue and trophic level determined by the food habits of yellowfin, skipjack, silky sharks, frigate tuna (*Auxis* spp.), flyingfishes, ommastrephid squids, and zooplankton (Figure 1). This work established that pelagic marine communities, in contrast to coastal marine communities, can have trophic structuring characteristics comparable to linear food chains. The same samples analyzed for Cs/K were analyzed for stable carbon isotope abundance by Rau et al. (1983). Average increase in standardized $\delta^{13}C$ per trophic level was 0.73 ‰ (Figure 1), establishing that stable carbon isotope ratios provide a valid tool for determining relative trophic position of pelagic predators in the ETP. While $\delta^{13}C$ is known to increase by about 1 ‰ within single trophic level steps, a ratio of nitrogen isotopes, $^{15}N/^{14}N$ ($\delta^{15}N$), appears to be a better indicator of trophic level than carbon isotopes because it increases on the order of 3 ‰ per trophic level (DeNiro and Epstein 1978; Fry and Sherr 1984). Of course, trophic relationships often change during an animal's ontogeny (Werner and Gilliam 1984) and in response to the abundance and distribution of its prey. This especially complicates the study of pelagic predators because their diet can vary greatly due to their broad distribution and mobility (e.g. Alverson 1963). Chemical and isotope constituents of muscle tissues integrate these changes, however, and reflect an animal's feeding history. Analyses of stable isotopes and stomach samples in conjunction can provide an indication of both the long-term and immediate trophic interactions of associated animals.

In this study, muscle tissues from 40-50 yellowfin, dolphins, and associated upper-level predators will be sampled from a minimum of two dolphin sets and two log sets each. The abundance of ^{12}C, ^{13}C, ^{14}N, and ^{15}N isotopes will be measured to determine if the yellowfin and dolphins occupy trophic positions similar to those indicated by the stomach contents. Smaller numbers of a metabolically-active tissue known to have high biomass turnover rates (e.g. heart) may be analyzed to look at shorter-term trophic status. The cost of mass spectrometry for

measuring isotope abundance is high, and the feasibility of analyzing samples from a greater proportion of the sets sampled for stomachs will be determined by this pilot study.

Procedures

IATTC observers will sample the catch of purse-seine vessels at sea during normal fishing operations of primarily the Mexico, Venezuela, and Vanuatu fleets. Sampling effort will be stratified in four regions, north of 20°N, 10°-20°N, 0°-10°N, and south of 0°, to encourage better coverage of the EPO. If a minimum of 5 dolphins of a single species can be collected, then samples from 25 yellowfin tuna will be collected as well. Although a sample size of 5 is relatively small, sets in which large numbers of dolphins are killed are not common, especially in recent years (Figure 2). Paired samples from the same set will consist of 5-25 dolphins and 25 yellowfin tuna. As many animals as practical will be sampled from species caught in association with the dolphins and tuna. These may include bigeye tuna (*T. obesus*); skipjack tuna (*Katsuwonus pelamis*); black skipjack tuna (*Euthynnus lineatus*); six species of billfishes: black marlin (*Makaira indica*), blue marlin (*M. nigricans*), striped marlin (*Tetrapturus audax*), shortbill spearfish (*T. angustirostris*), sailfish (*Istiophorus platypterus*), and swordfish (*Xiphias gladius*); several species of sharks, especially: silky (*Carcharhinus falciformis*), oceanic whitetip (*Carcharhinus longimanus*), thresher (*Alopias vulpinus*), mako (*Isurus oxyrinchus*), and hammerhead (*Sphyrna* species); wahoo (*Acanthocybium solandri*); and dolphinfishes (*Coryphaena hippurus* and *C. equiselis*). The yellowfin and other fishes from sets not associated with dolphins will also be sampled. The sampling priority by set type are: dolphin sets (any species), log sets, and school sets. Sets in the early morning will be given priority over late-afternoon sets and those at other times of the day. Stomachs will be taken over the size range of fishes caught, but tissues for isotope analysis will be taken only from the largest fishes. Young dolphins likely to be nursing will not be sampled.

Immediately upon brailing the purse-seine catch on board, each animal will be identified to species, measured, and sexed by scientific technicians. Intact stomachs will be removed using standard procedures, and frozen. A small sample of muscle will be removed from the dorsal region with a cork borer and frozen. The stock, coloration pattern, and lactation condition will be recorded for each dolphin processed. The IATTC has obtained permission to cut tunas at sea previously for a recent study, but in some cases it may be necessary to purchase the tunas sampled. If it is impossible for the technician to sample the fishes at sea, he will attach numbered Herculite flags to the caudal peduncles and deposit them in the holds with the rest of the catch. Flagged animals will be processed after unloading.

The stomach samples will be analyzed using standard procedures at IATTC's headquarters in La Jolla subsequent to rough sorting at IATTC's field labs in Mexico, Venezuela, Panama, and Ecuador. Food particle size and degree of digestion will also be determined. The stomach contents data will be converted to predation rates by adjusting for differential rates of gastric evacuation for the yellowfin (Olson and Boggs 1986; Olson and Mullen 1986) and skipjack (Magnuson 1969). The gastric evacuation rates of other species will be inferred from existing data (e.g. Stillwell and Kohler 1985). Muscle samples will be analyzed for stable carbon and nitrogen isotopes by a laboratory equipped with a mass spectrometer and operated by in-house

personnel experienced in these analyses (e.g. G. H. Rau, NASA-Ames Research Center, Moffett Field, CA).

Budget

Personnel	
Partial funding for 1 Associate Scientist for 2 yr	$51,000
Field equipment: dissecting equipment, sample preservation and storage supplies	3,000
Laboratory equipment	
Electronic balance	2,000
Dissecting scope & illuminator	2,000
Jars & preservatives	3,000
2 freezers for field offices	2,000
Miscellaneous	2,000
Isotope laboratory analysis - mass spectrometry	20,000
Travel	7,000
Shipping of equipment & specimens	6,000
Purchase of fish sampled at sea - 1 yr	
12 time-area strata, 10 samples (sets) each, 25 yellowfin per sample, 45 lb per fish average, $1000 per ton	68,000
TOTAL	$166,000

The purchase of fish sampled shall be at the market rate at the port of unloading, shall not exceed $68,000, and shall be supported by receipts or similar documentation. If less is actually spent for fish, the balance, not to exceed $14,000, shall cover a portion of the personnel costs. If less than $14,000 remains from the purchase of fish, the balance shall be allocated from any funds appropriated in FY 1993 for "dolphin-safe" research. If such funds are not allocated, sampling shall be curtailed so that the purchase of fish is reduced by $14,000.

All equipment purchased to conduct this study is accountable and will remain property of the National Oceanic and Atmospheric Administration, however, IATTC is guaranteed excusive use of the equipment for at least ten years from the purchase date of the equipment.